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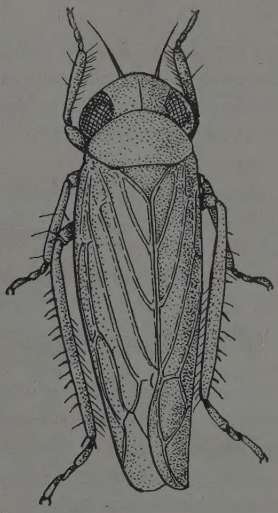
THE BEET LEAFHOPPER



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THE BEET LEAFHOPPER is a serious pest of sugar beets, several vegetable crops, and ornamental plants in the western part of the United States. It rarely becomes sufficiently abundant to cause great damage by its feeding, but the virus of the curly top disease, which it carries, is very destructive.

This leafhopper breeds in desert weeds early in the spring and migrates into cultivated areas late in the spring or early in the summer. There it produces one or more broods, the last of which migrates back to the desert in the fall.

Because of its migratory habits and the injury done by the disease which it carries, control by ordinary methods is rarely successful.

Planting varieties of sugar beets resistant to the disease has greatly reduced the damage and extended the cultivation of sugar beets into areas formerly regarded as unsuitable.

In many areas the control of grazing is the most feasible method of attacking the host plants of the beet leafhopper, but in some sections the reduction or elimination of Russian-thistle, the most important summer host of the beet leafhopper, by mechanical means is possible.

Damage to beets, and possibly to some other crops, may be reduced by timing the planting date with reference to leafhopper migrations.

Washington, D. C. Issued November 1941

THE BEET LEAFHOPPER

By W. C. Cook, *entomologist, Division of Truck Crop and Garden Insect Investigations, Bureau of Entomology and Plant Quarantine*[1]

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THE beet leafhopper (*Eutettix tenellus* (Baker)), referred to commonly in the West as the "whitefly," is a tiny insect slightly more than one-eighth of an inch long, varying in color from gray to greenish yellow. As the name implies, the insect, when disturbed, usually takes off for a short flight with a hop.

So far as known, the beet leafhopper is native to the western part of the United States and northern Mexico, where it is found breeding on many species of introduced weeds now generally established in the desert and range lands. When these weeds, which are principally short-lived annuals, mature and dry, the leafhoppers are forced to find new food plants, and often migrate long distances. Generally, however, the movement is from the desert or range land to adjacent cultivated areas. In the course of these movements cultivated crops, such as sugar beets, tomatoes, beans, and spinach, become infested.

THE BEET LEAFHOPPER, CARRIER OF THE CURLY TOP DISEASE

Beet leafhoppers rarely become sufficiently numerous to cause any great direct damage by their feeding activities, but they carry and transmit the virus of the very destructive disease known as curly top of sugar beets and western yellow blight of tomatoes. In addition to sugar beets and tomatoes, the curly top virus also affects garden beets, Swiss chard, spinach, nearly all varieties of beans, and various species of the melon family. Many ornamental flowering plants, including stocks, petunias, nasturtiums, zinnias, and geraniums, are also

[1] In the preparation of this bulletin unpublished information has been made available to the author by several members of the staffs of the Bureau of Entomology and Plant Quarantine and of the Bureau of Plant Industry assigned to sugar-beet insect investigations and sugar-beet investigations, respectively. Special acknowledgment is made of the assistance of R. L. Piemeisel, of the Bureau of Plant Industry, and of C. F. Henderson and F. R. Lawson, of the Bureau of Entomology and Plant Quarantine, who prepared parts of this bulletin.

The section on Natural Enemies was prepared by C. F. Henderson; that on Control of Host Plants by Protecting Natural Cover, by R. L. Piemeisel and F. R. Lawson; and that on Control of Host Plants by Mechanical Methods, by F. R. Lawson.

affected by the disease. When the leafhoppers enter the cultivated areas only a small percentage of them may be carrying this virus, but if large numbers of leafhoppers are present, those not carrying the virus soon pick it up from plants infected by the carriers. A single leafhopper may transmit the disease to several plants, and a few leafhoppers may cause severe damage if the plants are in the seedling stage.

For years the curly top disease has been a factor limiting the production of sugar beets in many western areas. Many beet-sugar factories have been built, operated for 2 or 3 years, and then abandoned because of the presence of this disease. In other areas, where the damage is not regularly extensive, the acreage of sugar beets has fluctuated greatly, being reduced after each severe outbreak of the disease and then gradually increasing until another outbreak occurred, with attendant losses both to sugar companies and to beet growers. Even in those areas where sugar-beet culture has become established on a relatively permanent basis, total crop failures have not been rare. The development and successful production of strains of beets resistant to curly top has greatly reduced the magnitude of these losses.

SYMPTOMS OF CURLY TOP

In beets the first easily recognized symptom of curly top is a clearing of the tiny veinlets of the youngest leaves, leaving a fine network of veinlets that appear transparent when the leaf is held against a light. This is followed by a growth of warty protuberances on the veins on

FIGURE 1.—Sugar-beet plant infected with curly top, showing the typical curling of the leaves.

the underside of the leaves, then by a curling of the leaves (fig. 1), and a general stunting, often ending in the death of the plant.

Occasional plants will show definite symptoms early in the season, and these will disappear later, so that the beet looks normal at harvest time.

In tomatoes the first reliable symptom of the curly top disease is a general drooping, but not wilting, accompanied by yellowing of the younger leaves. The plant is abnormal in color and often silvery in appearance. The leaves thicken and become crisp to the touch, and the entire plant turns yellow and eventually dies. Usually in severely diseased tomato plants no more fruit is set after the symptoms become obvious, and fruits that are already formed ripen prematurely, are stunted, and are of poor quality.

LIFE HISTORY OF THE BEET LEAFHOPPER

The eggs of the beet leafhopper are laid inside the tissues of the leaves and stems of plants (fig. 2). The egg stage lasts from 5 days to a month, depending on the temperature. The young leafhoppers, known as nymphs (fig. 3, *A*), emerge from the eggs, thrust their beaks into the plant tissue, and immediately begin to suck the plant juices. When they first appear the tiny nymphs are white, but in a few hours they darken considerably. As they grow, they shed their skins five times, becoming larger after each molt (fig. 3, *A–E*). The older

FIGURE 2.—Eggs of the beet leafhopper embedded in the tissue of a beet plant. Enlarged approximately 5 times.

nymphs are usually spotted with red and brown. After the fifth molt they are adult and possess wings. The adults (fig. 4, *A–C*) mate, and the females lay eggs for another brood. The adults range from gray to greenish yellow at different times during the year, being darker when they have developed during cool weather (fig. 4, *C*) and lighter when produced in hot weather (fig. 4, *A*) while an intermediate-color form (fig. 4, *B*) is produced during the spring.

The time required for the complete life cycle is greatly shortened at high temperatures. In midsummer a brood may develop in a month, whereas in the spring or fall from 6 weeks to 2 months may be required.

NUMBER OF BROODS

The beet leafhopper breeds continuously during the warmer months, and nymphs may be found at any time during the growing season. In California and Arizona nymphs are produced in every month except December and January. In the northern parts of its range

three broods are produced each season, while in the hotter parts of California and Arizona five or more broods may develop. One or two broods are usually produced in the desert before the spring migration, and two or more broods are produced later in the season.

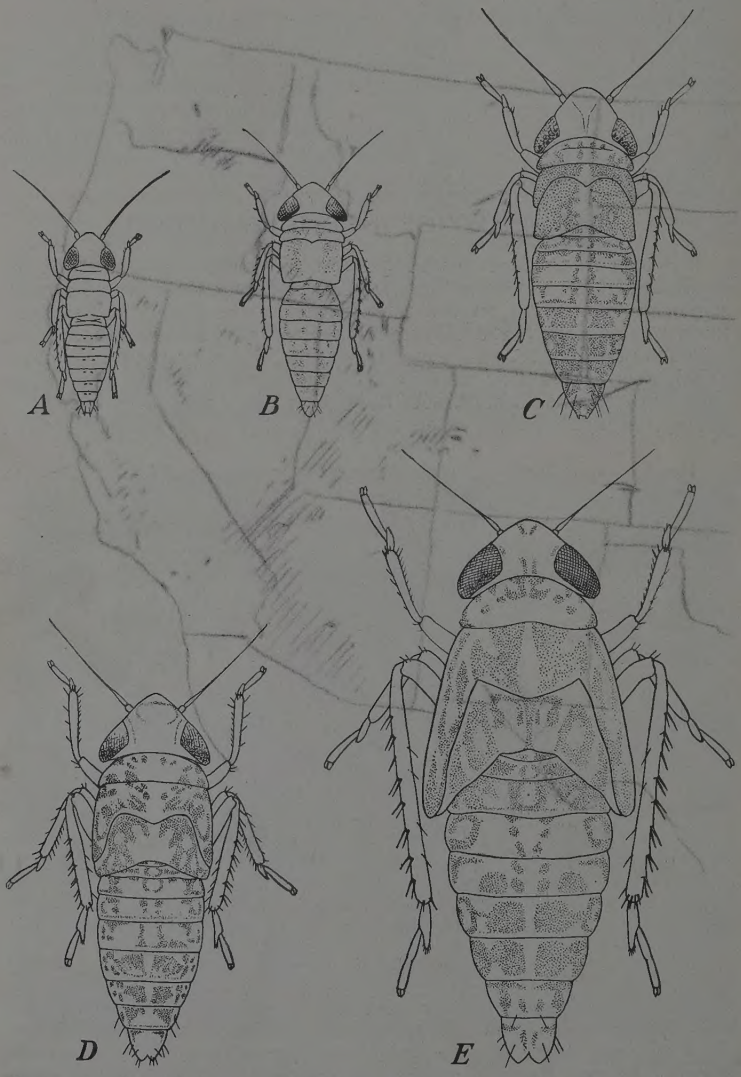

FIGURE 3.—Nymphal stages of the beet leafhopper: *A*, First instar; *B*, second instar; *C*, third instar; *D*, fourth instar; *E*, fifth instar. All enlarged 20 times.

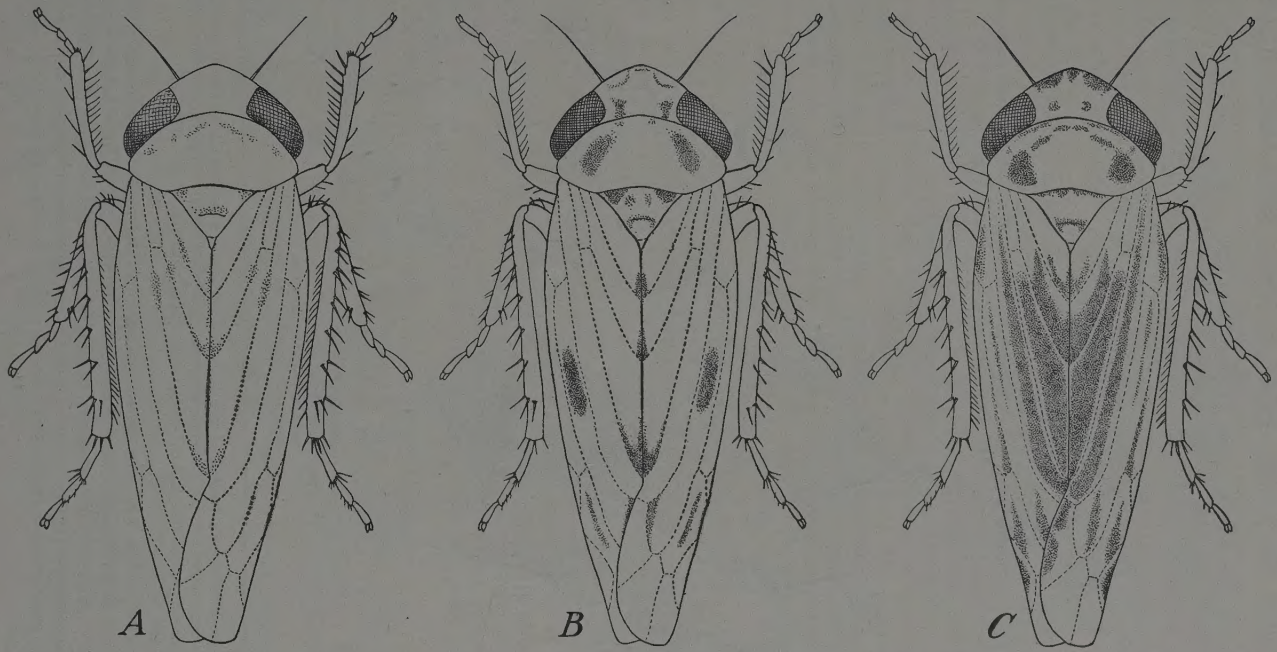

FIGURE 4.—Adults of the beet leafhopper, illustrating the variation in the intensity of color of individuals produced in different seasons of the year: *A*, Summer, or light, form; *B*, spring, or intermediate, form; *C*, winter, or dark, form. All enlarged 20 times.

BREEDING GROUNDS, HOST PLANTS, AND MIGRATIONS

Most of the plants upon which the beet leafhopper breeds are annuals that are rather short-lived. The leafhoppers move at about the time these plants mature and dry. They travel with the wind and

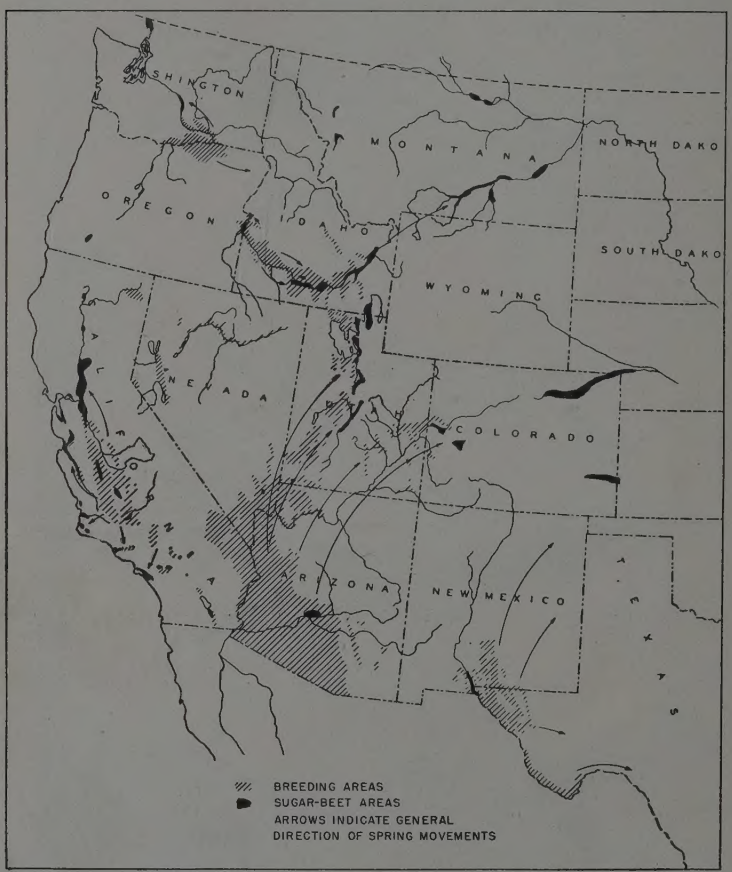

FIGURE 5.—The major breeding grounds of the beet leafhopper and the sugar-beet areas affected by them. Breeding grounds are shown by lined areas, the sugar-beet areas by solid black, and the directions of movement by arrows.

infest practically all the host plants in their path. Nearby host plants are heavily infested, and those farther away are more lightly infested. A sufficient number of leafhoppers to cause serious damage may reach crops 100 miles or more from the place of origin, sometimes crossing mountain ranges and deserts that lie in the direction of the movement.

Most of the favored host plants are weeds, and the infestation of crop plants is incidental to the general movements, as the leafhoppers do not actively seek out crop plants but infest any favorable hosts in their path. After the spring migration the leafhoppers will remain and breed prolifically on beets, to a lesser extent on spinach and Swiss chard, and very lightly, if at all, on the other crop plants. The leafhoppers can live for only a short time on tomatoes and beans, and these crops are infected with curly top principally during movements of the insect.

The host plants of the beet leafhopper usually occur in large patches scattered over definite areas. Such areas where large numbers of favorable host plants combine with favorable climatic conditions are very productive of leafhoppers and are commonly called breeding grounds. While it is very difficult to trace the flights of so tiny an insect and much remains unknown about their movements, yet it is known in a general way that leafhoppers from any one breeding ground infest the same cultivated areas year after year. An attempt has been made to show on one map (fig. 5) the larger breeding grounds of the beet leafhopper, the localities in which sugar beets are grown in the West, and the general routes followed by the leafhoppers in their spring migrations. Many other small breeding areas have been found, and these are often of great local importance, but such small areas cannot be shown on a map of this scale.

All these breeding grounds except the one along the Rio Grande in Texas and New Mexico are west of the Continental Divide. All are in arid country with a mean annual rainfall of not over 10 to 12 inches. In all except the Rio Grande and Arizona areas the summers are very dry, and the heaviest rains fall during the winter or spring. In Arizona, New Mexico, and western Texas there is appreciable winter rainfall, with another rainy period late in summer. The quantity and distribution of rainfall in all these breeding grounds is such that practically all agriculture depends on irrigation. The summers are hot and dry in all the breeding areas, but the winter climate varies greatly. To the north, heavy snows and subzero temperatures are not uncommon; to the south the moisture falls as rains, and the winters are short and cool.

The map (fig. 5) shows six general areas which seem to be nearly independent of each other so far as leafhoppers and curly top are concerned. These are: (1) Washington and Oregon; (2) California; (3) southern Idaho; (4) Utah, Nevada, and northwestern Arizona; (5) southern Arizona and western Colorado; and (6) New Mexico and western Texas.

To bring out the similarities and differences, these areas will be discussed individually in the order given.

WASHINGTON AND OREGON

In Washington and Oregon (fig. 5) the breeding areas lie east of the Cascade Mountains in an arid region which has cold, wet winters and hot, dry summers. The fall rains usually begin in October, and the winter vegetation normally germinates before the middle of November. The chief summer host of the beet leafhopper, Russian-thistle (*Salsola pestifer* A. Nels.), is usually dry in October, so for a

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short period the leafhoppers may be forced to feed on sagebrush (*Artemisia tridentata* Nutt.) and rabbitbrush (*Chrysothamnus* spp.). If the Russian-thistle dries before the winter hosts germinate, there may be a heavy mortality of these insects, but if it remains green until winter hosts are germinated the mortality is greatly reduced, and high leafhopper populations enter the winter. Filaree (*Erodium cicutarium* (L.) L'Her) and tumblemustard (*Norta altissima* (L.) Britton) are the most important winter hosts, and filaree, or alfilaria, is the more important of the two because of its abundance.

The leafhoppers are usually inactive for much of the time during December and January. In the spring the eggs for the spring brood are laid, principally in tumblemustard. When this plant matures, the leafhoppers move to Russian-thistle or to cultivated crops, where two more broods are produced. With the drying of the thistle or the harvesting of cultivated crops, the leafhoppers move back to hold-over hosts or to filaree, completing the cycle.

This region is well suited for the production of sugar beets so far as soil and climate are concerned, but all attempts to produce this crop failed until the introduction of varieties resistant to curly top, which are now extensively grown. The region is also climatically well suited to tomato growing, but very few tomatoes are grown because of the severity of the curly-top infection.

CALIFORNIA

The majority of the breeding areas in California (fig. 5) lie in the San Joaquin Valley, but there is some scattered breeding along the western edge of the Mojave Desert and in southern California. Practically no rains fall in this territory between June 1 and October 1, and the heaviest rains come in December, January, and February. The winter is cool, with occasional frosts, but the weather is usually warm enough to enable the leafhoppers to remain active during the entire year. The largest winter breeding grounds are in the eastern or inner foothills of the Coast Range, on the west side of the San Joaquin Valley. The chief winter host is filaree.

When the weather moderates in February and March, the over-wintered females lay their eggs in various range weeds, especially in peppergrass (*Lepidium nitidum* Nutt. and *L. latipes* Hook.) and desert plantain (*Plantago insularis* Eastw. and *P. erecta* Morris). One complete brood and a partial second are produced in the foothills before the vegetation dries. With the drying of the range plants, the spring broods leave the foothills and migrate into the cultivated areas in the valley bottoms. Here they settle upon their summer hosts, which are Russian-thistle, bractscale (*Atriplex bracteosa* Wats.), fogweed (*A. expansa* (D. and H.) Wats.) and some other plants, including sugar beets. These migrating leafhoppers transmit the virus of the curly top disease, and at this time (April and early May) the damage to cultivated crops begins.

Several broods of leafhoppers are produced upon the summer host plants, and the leafhoppers remain in the lowlands until the weed hosts mature or the crops are harvested. During October and November they drift back into the foothills of the Coast Range. At this time, before the fall rains have begun, few or no favorable annual host plants are present, and the leafhoppers congregate upon what green vegeta-

tion is available, which consists principally of patches of perennial plants in the bottom and on the sides of dry washes and on the valley floor. As in the Washington and Oregon area previously discussed, they must remain on these hold-over hosts until the rains cause the winter annual host plants to germinate, and a considerable mortality may take place if the rains are greatly delayed. With the coming of the winter rains the leafhoppers leave the hold-over plants and feed on the newly germinated annuals.

Sugar beets are extensively grown in the Sacramento Valley, the Salinas Valley, and scattered areas in southern California. Attempts have been made to grow beets in the San Joaquin Valley, but, until very recently, these have ended in failure, owing to curly top. In 1936 about 2,000 acres of beets resistant to curly top were planted in the San Joaquin Valley, and these plantings proved successful. In 1937, 13,500 acres were planted. A large acreage of tomatoes also is grown each year in the Sacramento Valley.

SOUTHERN IDAHO

The sugar beet territory of southern Idaho (fig. 5) consists principally of a relatively level plain adjacent to the canyon of the Snake River. The temperatures here are very similar to those in the Washington-Oregon area, but the rainfall is more evenly distributed. The heaviest rains come in the spring and fall, but light rains may fall in any month.

The winter vegetation normally germinates in October or November, but in some seasons no succulent vegetation is available before the winter season begins, and the leafhoppers are forced to winter in and around sagebrush. The spring breeding host plants are tumble-mustard, green tansymustard (*Descurainia longipedicellata* (Fourn.) O. E. Shulz), and flixweed (*D. sophia* (L.) Wats.). When these plants mature the leafhoppers migrate to Russian-thistle and sugar beets. In the fall they may move directly from their summer hosts to their winter and spring hosts unless they are forced to spend some time on sagebrush.

In eastern Idaho beets have been successfully grown for many years, but in south-central Idaho sugar beet production has been very irregular and intermittent, the number of acres grown each year in the Twin Falls area ranging from practically none to 30,000. Since the introduction of varieties of sugar beets resistant to curly top the acreage has been stabilized in the vicinity of 25,000 acres. The climate and soil are suitable for tomatoes, but curly top restricts tomato growing to the production of fresh fruit for local markets. White beans and garden varieties for seed are grown commonly in this territory but are subject to periodic losses from curly top disease. Red Mexican beans are generally grown, as these are highly resistant to curly top attack.

UTAH, NEVADA, AND NORTHWESTERN ARIZONA

Northern and central Utah (fig. 5), where the irrigated crops are grown, and the southern Utah-Nevada-Arizona area, where the winter breeding of leafhoppers occurs, are really two distinct areas. In the cultivated areas the winter climate is severe, with a light snow cover during the greater part of that season. The temperature and rainfall distribution is similar to that described for the Idaho area. In the

winter breeding areas the winter conditions are nearly as mild as in California, and the leafhoppers are inactive only during December and January.

The leafhoppers overwinter in the southern area on alfilaria, or filaree, and other annual winter host plants. One or more generations are produced on these annuals before they dry up in the spring. With the drying of the vegetation, the insects move northward over the Escalante Desert, infesting extensive areas of Russian-thistle which are situated immediately to the north and causing severe damage to sugar beets in the Sevier Valley to the northeast. Though some of the leafhoppers travel as far north as Salt Lake City, they are usually too few in numbers to do any direct damage in that district, which is usually more severely infested by leafhoppers from the local breeding grounds mentioned in the following paragraph. Their progeny, however, contribute to the numbers of the spring brood in the local breeding grounds of the district. The Escalante Desert is considerably higher than the southern breeding grounds, and the leafhoppers breed here during the summer, when there are no host plants in the lower areas. The fall generation of leafhoppers that is produced in the Escalante Desert moves southward into the winter breeding grounds during September and October, where it remains upon creosotebush (*Covillea tridentata* (DC.) Vail) and other desert shrubs until the winter annuals sprout. Sufficient rain to cause sprouting of these annuals may often be delayed, and under these conditions a high leafhopper mortality ensues.

In northern Utah there are several small local breeding areas, where the leafhoppers may overwinter on alfilaria, or filaree, and produce a spring generation on several plants, especially two introduced mustards (*Cheirinia repanda* (L.) Link and *Malcolmia africana* (L.) R. Br.). This spring brood is reinforced by the progeny of migrants from the southern breeding grounds, as previously mentioned. The summer broods are produced on Russian-thistle and beets, and fall rainfall is sufficient to cause alfilaria to germinate in most seasons before the summer hosts dry. In some years a very short period may occur when hold-over hosts such as sagebrush maintain the leafhopper.

Sugar beets have been grown in Utah as far south as the Sevier Valley for many years. Frequently they have been severely damaged by curly top. The damage has usually been greatest in the Sevier Valley, and very light in the Cache Valley, which is separated from both local and distant sources of leafhoppers. Tomatoes are rather generally grown as a commercial crop in northern Utah, but are often severely damaged and occasionally destroyed by curly top.

SOUTHERN ARIZONA AND WESTERN COLORADO

Southern Arizona (fig. 5) has been found to be the source of most of the leafhoppers infesting the cultivated areas of western Colorado; therefore these two areas, which differ greatly in climate and crops, are treated together. There are small local breeding grounds scattered along the drainage of the Colorado and Green Rivers in Utah and western Colorado, but winter conditions and host plants are unfavorable in these districts, and the leafhoppers produced here would be of little importance were they not reinforced by early flights from Arizona.

The Colorado-Utah area is similar in general climate to the northern Utah areas just discussed, except that the rainfall is very scanty and is distributed throughout the year.

The climate of southern Arizona is characterized by long, hot summers and short, cool winters. There are winter rains during December, January, and February, and summer rains during July and August. The total rainfall is very light.

The beet leafhopper overwinters in southern Arizona on such winter annuals as the peppergrass *Lepidium lasiocarpum* Nutt. and patata (*Monolepis nuttalliana* (Schultes) Green). Desert plantains, chiefly *Plantago fastigiata* Morris, grow everywhere with the peppergrass, but there is apparently very little breeding of the beet leafhopper on these plants. The first spring brood usually moves northward late in April, infesting Russian-thistle and cultivated crops in northern Arizona, southeastern Utah, northwestern New Mexico, and southwestern Colorado, often reaching as far north into Colorado as the Grand Valley. The second brood moves northward from southern Arizona late in May. Their numbers may be increased en route by spring-brood adults produced in more local breeding grounds. This northward movement is the principal source of leafhopper infestation and curly top disease in western Colorado and eastern Utah. Nearly all the leafhoppers leave the desert areas of southern Arizona by the early part of June, and it is not until late in July, when the summer rains occur, that these areas are repopulated by movements of leafhoppers from peppergrass that grows in areas southeast of the chief breeding area. The summer rains cause the germination of chinchweed (*Pectis papposa* Harvey and Gray) and other plants, (*Tidestromia languinosa* (Nutt.) Standl. and *Trianthema portulacastrum* L.), which serve as summer hosts, and upon these as many as two broods of leafhoppers may be produced before these plants die in the fall. If the late fall rains do not bring about germination of the winter hosts before the summer hosts die, it becomes necessary for the leafhoppers to shift to hold-over hosts, as in other areas.

Sugar beets and tomatoes are grown commercially in western Colorado, but occasionally suffer heavy damage. Sugar and table beets are grown for seed in the Salt River Valley of Arizona, and they may be infected in the fall with curly top. Tomatoes and squash are injured by curly top disease in the spring.

NEW MEXICO AND TEXAS

The only breeding area of any size east of the Continental Divide is that which lies north and east of the Rio Grande in southern New Mexico and the extreme western and southwestern part of Texas (fig. 5). Here there is both summer and winter rainfall. Throughout the warmer months the beet leafhopper breeds on a perennial peppergrass (*Lepidium alyssoides* Gray). During August and September the majority of the leafhoppers leave the peppergrass and breed on summer host plants similar to those in the Arizona area. When the fall rains occur new growth is produced in the old peppergrass crowns, and new seedlings sprout. The leafhoppers then return to this plant.

The leafhoppers remain in this area throughout the year. Two spring broods are produced on the peppergrass, and surplus populations of the leafhoppers move northward early in May and early in

June. Areas as far north and northeast as Pueblo, Colo., and Amarillo, Tex., are infested by flights of leafhoppers from this breeding area. In the fall, leafhoppers from this area drift southward into nearby agricultural areas, where they infest fall crops.

Another smaller breeding ground farther down the Rio Grande, with a host-plant complex similar to that of southern Arizona, has been discovered very recently. This is apparently of small importance in the spring, but fall populations drift to the southeast into cultivated districts.

Sugar beets grown near Springer and Las Vegas, N. Mex., are often severely infested, and occasionally flights of the leafhoppers find their way into the Arkansas Valley in Colorado from this source. Tomatoes, beans, and melons are also infested in these spring flights. The fall flights affect beets grown for seed and spinach fields in the Rio Grande Valley, sometimes doing severe damage to spinach in the "winter garden" area near Del Rio, Tex.

NATURAL ENEMIES

Throughout the western part of the United States large numbers of beet leafhoppers are destroyed each year by their natural enemies. These parasites and predators attack the beet leafhopper in all its stages and under certain conditions are undoubtedly of great importance. It is difficult to estimate what the status of this pest would be if it were not for the influence of these beneficial insects.

Large numbers of eggs are destroyed by minute parasitic wasps that develop within them. In southern Idaho it is not uncommon to rear from 25 to 30 of these minute parasites from a square foot of Russian-thistle in the fall, a fact which indicates an enormous destruction of leafhopper eggs in this widespread summer host. Many of the eggs destroyed are those of other leafhoppers. Large numbers of egg parasites have also been reared from this and other summer hosts in California, Arizona, and other areas within the range of the beet leafhopper. In addition to these parasites, various predaceous bugs unquestionably destroy a number of eggs of the beet leafhopper.

The nymphs and adults of the beet leafhopper are attacked by three groups of internal parasites—the big-eyed flies, the parasitic wasps, and the twisted-winged parasites. The flies and wasps deposit their eggs in or on the leafhopper, and the resulting larvae develop within, or partly within, its body. Upon reaching maturity, the larvae work out of the leafhopper, causing its death. The twisted-winged parasites develop differently, the female remaining within the body of the leafhopper during its entire life and giving birth to living young. These tiny larvae crawl away, attach themselves to the first leafhopper found, and bore into its body. They seldom become of any real importance, since the chances of their finding leafhoppers in which to develop are slight.

The big-eyed flies, one of which, *Pipunculus subnitens* Cress., is shown in figure 6, are probably the most important parasites of the beet leafhopper. These flies are widespread in their distribution and occasionally very abundant. For example, in southern Idaho as much as one-fourth of the fall brood of leafhoppers may be attacked by them. This means a corresponding reduction in the number of eggs laid the following spring, since parasitized female leafhoppers rarely,

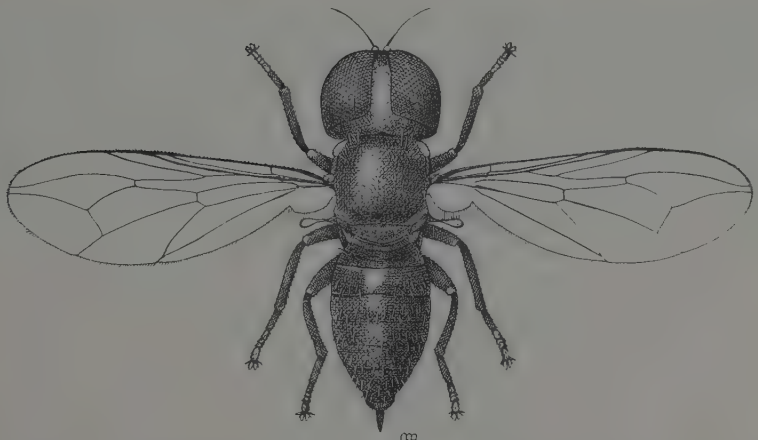

FIGURE 6.—*Pipunculus subnitens*, one of the species of big-eyed flies which are parasitic upon the beet leafhopper; enlarged 15 times.

FIGURE 7.—*Gonatopus* sp., one of the parasitic wasps which prey upon the beet leafhopper; male; enlarged 15 times.

if ever, lay eggs. In certain localities nearly two-thirds of the leafhoppers have been found to contain maggots of these flies, but this is unusual. This parasite spends the winter as a larva within the body of the leafhopper.

The parasitic wasps (*Gonatopus* spp.) may be classified both as parasites and as predators, since they not only deposit eggs which hatch and develop within the host but also quite often seize and mangle the prey with their pincerlike claws, thereby causing immediate death. Normally, however, the wasps are considered as parasites, as it is in

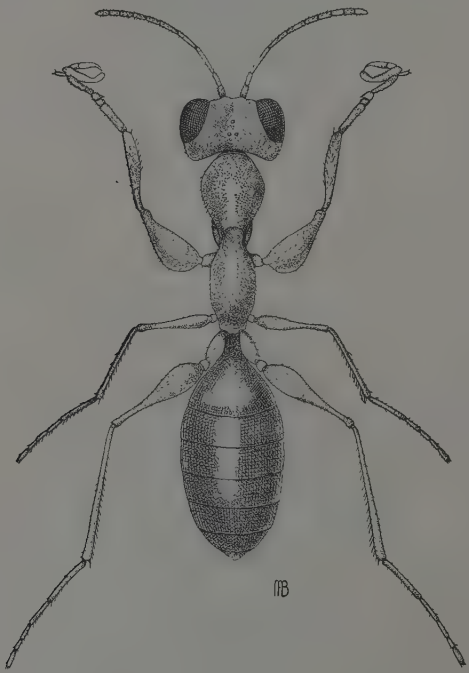

FIGURE 8.—*Gonatopus* sp., female; enlarged 15 times.

this role that they are of the greatest importance in reducing populations of the beet leafhopper. The male wasp has wings (fig. 7), while the female is wingless (fig. 8) and very closely resembles an ant in appearance as well as in movements. The female is very active, especially in the presence of leafhoppers, seizing one after another with great speed. Before the egg is laid the leafhopper is stung, which causes temporary paralysis. The larval stage of the parasite is spent within a dark-colored sac which protrudes from the abdomen of the leafhopper, and is plainly visible. Several species attack the beet leafhopper.

Several species of predaceous bugs, one of which (*Geocoris pallens* Stål) is illustrated in figure 9, destroy large numbers of the beet

leafhopper and are probably as important as the parasites in reducing its numbers. These insects insert their beaks into the bodies of the leafhoppers or other insect attacked and suck out the body juices. They are general feeders and do not limit their attack to leafhoppers.

Spiders, lizards, and birds also play a part in reducing the numbers of the beet leafhopper. The effect of these groups of predators, however, is difficult to measure, although field observations indicate their role to be an important one.

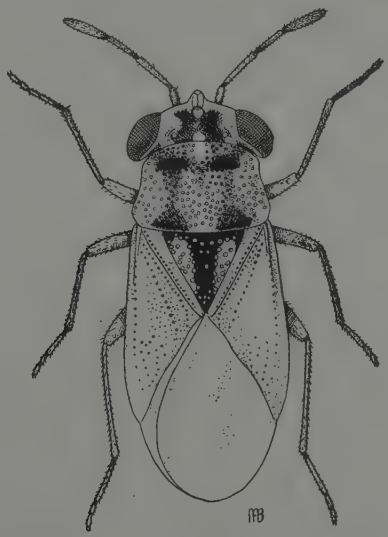

FIGURE 9.—*Geocoris pallens*, a predaceous bug that feeds on the beet leafhopper enlarged 20 times.

CONTROL OF THE BEET LEAFHOPPER

Because this insect is migratory in habits, and also because the damage is caused by the virus of the curly top disease which it carries, and not by the mass feeding of the insect alone, the control of the beet leafhopper is a difficult problem. Direct control by spraying in the beet fields will be of value only if it can be done very shortly after the leafhoppers enter a field, and before they have had much chance to spread the disease. Indirect methods for its control have been tried with more or less success for several years, but the problem is far from solved.

PLANTING RESISTANT VARIETIES OF BEETS

The Bureau of Plant Industry of the United States Department of Agriculture, working in cooperation with various beet-sugar companies, has developed several resistant varieties of sugar beets. These varieties are being widely planted, and their use has greatly reduced the

losses from curly top. The breeding work is being continued, and new strains are being made available as rapidly as they are developed.

Certain varieties of bean, squash, and pumpkin are naturally resistant, but the sugar beet is the only crop plant for which strains having resistance to curly top have been developed. Attempts are now being made to develop varieties of tomatoes and other varieties of beans possessing such resistance.

CONTROL OF HOST PLANTS OF THE LEAFHOPPER

Control of Host Plants by Protecting Natural Cover

The host plants of the beet leafhopper are usually divided into two groups, winter-spring hosts and summer hosts, according to the time of growth and maturity of the plants. The host plants may also be divided into two groups according to the situation in which they grow—those that grow on range land and those that grow on abandoned farm land. For discussion of control measures these groups can be combined into the spring hosts on range lands and the summer hosts on abandoned lands. There are some exceptions to this classification, such as two spring hosts (mustards) found on abandoned lands in Idaho and some summer hosts found on range land in Arizona.

The winter and spring hosts that carry the leafhoppers through the winter and produce broods before the spring migration takes place mature early and are dry in the summer. Nearly all these plants are annuals and occur on overgrazed range land. They are weeds in the sense that though they may be found in small quantities in good range land they increase rapidly in area and density as the original cover is destroyed and in time form the main cover in place of the more valuable forage plants. The control of these weeds as well as investigations of their manner of growth and spread has been the object of cooperative studies by the Bureau of Entomology and Plant Quarantine and the Bureau of Plant Industry. The extent of the weed areas and the distribution of the weeds were determined by surveys. The effects of overgrazing, fire, and other destructive agencies were studied on selected areas of range or abandoned land and by means of fenced plots.

These studies show that the most feasible method of controlling the range weeds that act as hosts is by controlling or eliminating the agencies destructive to the more desirable grasses. The most universal and by far the most important of these agencies is overgrazing, although locally fire, rodents, and other minor factors may be important.

In two protected plots in the San Joaquin Valley, Calif., the weed hosts of the beet leafhopper were greatly reduced by two seasons of protection from grazing. When one-half of each of these plots was moderately grazed, the weeds were not noticeably increased. In Idaho, under moderate grazing, weed hosts were replaced by nonhosts (annual grasses) in about 5 years, though locally on 20-acre weedy tracts protected from grazing such replacement was seriously interfered with by jack rabbits. When rodentproof fences were set up the replacement took place, and grasses instead of weed hosts formed the cover.

In any of the areas of weed hosts in the West the seeds of annual grasses, perennial grasses, or shrubs that are not hosts are present and will spread and eventually reduce or entirely replace the weeds if agencies that are excessively destructive to the cover are controlled or eliminated.

The summer hosts, upon which two to four broods are produced in different areas, present a somewhat different problem. In the southern areas from the Mojave Desert of southern California eastward to Texas the principal summer hosts are range weeds that can probably be controlled by the elimination of overgrazing, although there is very little evidence to indicate how long a period of time would be necessary for the satisfactory reduction of these weeds by grazing practices. In all the other breeding areas the studies of various workers on this problem have shown that high summer and fall populations of the beet leafhopper are produced on Russian-thistle (fig. 10) and that this is the most important summer host.

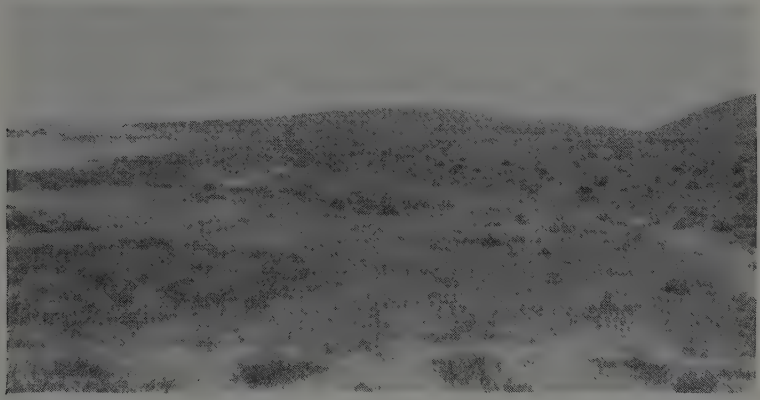

FIGURE 10. Russian-thistle growing on overgrazed range land in California.

Present knowledge indicates that the reduction of Russian-thistle to small areas would reduce leafhopper populations to a point where this insect would cease to be a serious pest in the greater part of the West. Careful study of this plant and its manner of growth has shown that it is definitely a weed, growing in poorly farmed or abandoned areas and on badly overgrazed range land. It is not abundant in well-farmed areas. The lands which are now growing dangerous stands of Russian-thistle may be classified in the following three groups: (1) Abandoned lands, formerly cultivated and now grazed; (2) temporarily abandoned or fallowed land; and (3), to a less extent, overgrazed land.

Throughout the West there had been an overexpansion of cultivation into areas that could not be continuously farmed. As a result, land was abandoned, and a luxuriant crop of Russian-thistle was produced. Where this land was left alone or moderately grazed, the Russian-thistle was replaced by grasses and other plants that are not leafhopper hosts and are usually of more forage value than Russian-thistle. In

many cases, however, these lands have been severely and continuously overgrazed, and this has prevented or limited the reseeding of other plants and so made conditions suitable for the continued growth of Russian-thistle. In the greater part of the West, Russian-thistle will disappear after 3 or 4 years if other plants are given a chance. The best method of reclaiming such areas therefore is to protect them against overgrazing. As on the range lands noted above, overgrazing is the most general destructive agency though locally there may also be need to protect against fire, rodents, or other minor factors.

In many places in the West there are sections which, because of an insufficient supply of irrigation water, are only temporarily or intermittently farmed. In dry years these sections are left fallow and produce stands of Russian-thistle. The permanent remedy in this case is a reorganization of irrigation districts and a consolidation of the irrigated lands into smaller, compact areas that may be continuously and profitably farmed. This is already being done on some irrigated tracts of land, not particularly because of any relation to the beet leafhopper problem but to bring about a more stabilized and more successful type of farming.

Control of Host Plants by Mechanical Methods

As compared with some other plants, Russian-thistle is not a difficult weed to control. In areas where the value of land and crops is sufficient, control of the weed is justified on the basis of its effect on the crops alone.

While the writer and his associates have had no experience with chemical control measures directed against Russian-thistle, the mechanical methods described in the following paragraphs have been tried experimentally, and it has been demonstrated that they may be applied successfully against either the immature or the mature plants. After seed is set on the plants, however, it is necessary to collect and burn or otherwise destroy them to prevent them from blowing about and scattering seed.

Several methods have been used to destroy the green, immature plants. Hand hoeing has become a standard practice in California as an adjunct to other control measures. Crews of men work over areas where small, compact stands of thistle occur and hoe out these patches before they seed. The cost of this operation has ranged from $1.25 to $1.50 per acre, according to E. A. Schwing, entomologist for the sugar companies, who was in charge of the work. In plowed fallow land, or in stubble where the soil is rather loose, Russian-thistle has been controlled very satisfactorily by the use of a 10-foot weeder blade mounted so as to cut about an inch under the surface. In one case three of these knives and three sections of hay rake were pulled by a large tractor covering a 30-foot swath. The Russian-thistle was cut and windrowed at a cost estimated at from 25 to 35 cents an acre.

The mature plants may be handled by other methods. Dragging with a railroad rail hauled by a tractor is a method that has been used to some extent. It works well only on stands of large plants. On this type of stand it greatly reduces the seeding and practically stops the rolling of mature plants, which is the way in which new

fields are seeded. The cost of this method was approximately 75 cents per acre.

Russian-thistle plants do not break loose and blow about extensively until after the first heavy rains. There is usually a period of a month or more between the maturity of the Russian-thistle or its death from frost and the commencement of rolling, during which it is possible to gather the plants and burn them. In the process of handling dry plants plenty of seed is scattered to reseed the field on which the Russian-thistle grew. However, most of these old fields will not grow important stands of thistle the next year because most of them will be intensively cultivated or completely abandoned; in the latter case Russian-thistle will grow so thick that it will kill itself out before maturity or be crowded out by other plants. Work on a fairly large scale in California has shown that the burning of mature plants will reduce the leafhopper infestation greatly by preventing the seeding of new fields. Two consecutive years of this type of work reduced the infestation to such an extent that only a small amount of hand work was necessary in the third season to keep the plant under control. The cost of this work, with relief labor, ranged on an average from 35 to 50 cents per acre, depending on the dryness of the plants and the density of the stand. In certain cases raking with a hay rake greatly reduced the cost.

On land that is permanently abandoned or on range land disturbance of the soil is undesirable because this retards the natural replacement of Russian-thistle by more desirable plants. Where it is desirable to remove thistle from abandoned fields or borderland ranges, dragging, burning, or hand hoeing are preferable to plowing and disking because they disturb the soil less. On land that carries a cover of grass, the thistles should be piled before being burned, and the grass cover should be left as nearly intact as possible.

DIRECT CONTROL OF THE LEAFHOPPER

Control on Sugar Beets

Many attempts have been made to control curly top disease on sugar beets by spraying the fields shortly after the spring migration of the leafhoppers. Most of these attempts have been of little value because the damage is done so soon after the leafhoppers arrive in the field.

Control in Breeding Grounds

In discussing the California breeding grounds, mention was made of the fact that in many areas the leafhoppers are forced to concentrate on small patches of perennial plants during the fall. This does not occur to any marked extent in any of the other breeding areas discussed. This concentration makes it feasible to kill large numbers of the leafhoppers in the foothill breeding areas and thus reduce sharply the number of insects starting into the winter. A program of fall spraying of leafhopper concentrations was begun by two sugar companies in the fall of 1931 and has been continued each fall since then.

The spray used is a mixture of pyrethrum extract in Diesel fuel oil, the extract of ½ to 1 pound of pyrethrum flowers being used in each gallon of oil. The oil is applied in an atomized form, without any

dilution, and at the rate of from 5 to 7 gallons per acre. Special machinery for the work was developed by the sugar companies. It uses a modified paint-gun nozzle, with an air compressor to furnish the air at about 75 to 80 pounds pressure. The whole outfit is mounted on a pick-up truck and has two leads of hose carried by men on foot (fig. 11). This machine is efficient and, with the use of the spray formula given above, regularly obtains kills of over 90 percent of the leafhoppers present.

Careful survey work since 1929 has shown that most of the leafhoppers that migrate to the lower San Joaquin and Sacramento Valleys are produced in the northern and central portions of the Coast

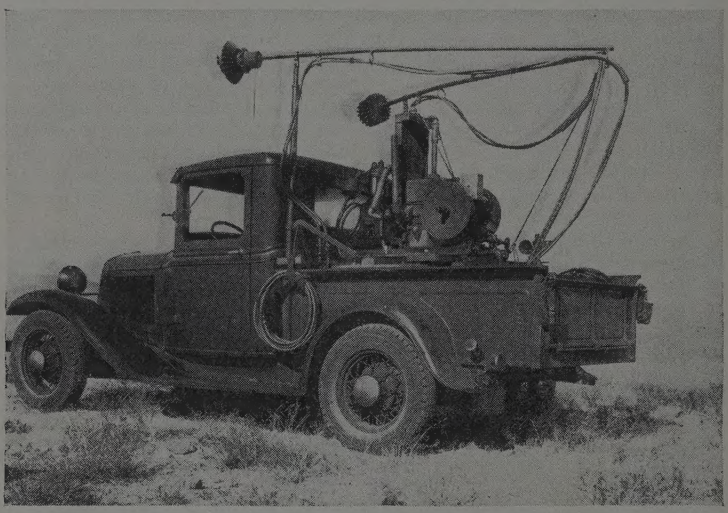

FIGURE 11.—Machine used for spraying the breeding grounds of the beet leafhopper in California. The gear wheels are merely counterweights for the spray booms.

Range foothills, where most of the control work has been done. It is rather difficult to estimate the populations of leafhoppers involved, but the consensus of opinion of several workers who have checked the results of the spray work is that between one-half and two-thirds of the leafhoppers in this area in the fall have been destroyed annually by spraying. This is roughly confirmed by the spring populations found in the beet fields.

Control on Beets Grown for Seed

Beets grown for seed in the New Mexico and Phoenix, Ariz., areas are sometimes subject to infestation by the beet leafhopper, particularly during the fall period. Experimental control of the leafhopper on these beets has shown that the infestation can be reduced very materially by the utilization of an oil spray containing pyrethrum, the material being applied with a specially constructed atomizing type of sprayer.

CHOOSING DATE AND PLACE OF PLANTING TO AVOID CURLY TOP DAMAGE

Sugar Beets

It has long been known that early planted beets in the Sacramento Valley of California will almost always escape serious damage from curly top. In this area most of the beets are therefore planted in January and February. March and April plantings are usually severely damaged.

Experience has shown that in the coastal area of California beets may be planted after the spring movement of the leafhopper and make a successful crop. This is only safe in those areas where summer breeding of the beet leafhopper is not important, as in most areas later broods of leafhoppers will cause damage.

In other parts of the West early plantings are not always satisfactory because of factors other than curly top, but experience has shown that early planted beets do not suffer so much from curly top damage as do the later planted ones.

Garden Beets Grown for Seed

At the present time many garden beets are grown for seed by the old-time method of growing small roots, or "stecklings," in small beds planted late in summer. In December and January the stecklings are transplanted into large fields and set out about 3 feet apart each way. To obtain healthy roots, it is necessary to avoid curly top infection in the root beds. This is best done by growing the stecklings in localities where they will not be exposed to leafhoppers. Many small areas have been found that are suitable for these plantings, and others may be located if necessary.

Tomatoes

Tomato fields planted before the first spring migration of the beet leafhopper are more liable to damage than those planted after migration. Growers in regions of short growing seasons or growers of the very early market tomatoes cannot wait for this, but in California and other regions with a long growing season it is advisable, in sections that are near spring-breeding grounds, to delay planting until the vegetation on these breeding grounds has dried and the leafhoppers have moved out, as plants in these sections are subject to very high infestation during the spring movements.

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